MIGRATING MORMON CRICKETS, *ANABRUS SIMPLEX* (ORTHOPTERA: TETTIGONIIDAE), AS FOOD FOR STREAM FISHES

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ABSTRACT.—Migrating bands of Mormon crickets (*Anabrus simplex*) were observed crossing the Green and Yampa rivers in Dinosaur National Monument, Colorado and Utah, in 1986 and 1987. Swimming crickets were swept downstream and eaten by four endemic and seven introduced fish species. Included were two endangered fishes, Colorado squawfish (*Ptychocheilus lucius*) and humpback chub (*Gila cypha*). Direct and indirect effects to aquatic food webs associated with application of pesticides for Mormon cricket control may pose a threat to these fishes and to man.

The Mormon cricket (*Anabrus simplex* Haldeman) occurs only in western North America where it is generally regarded as an agricultural pest (Wakeland 1959). This flightless, long-horned grasshopper is primarily solitary in low-density subpopulations but becomes gregarious and migratory with high densities, moving from its mountain breeding areas to plague croplands (Capinera and MacVean 1987). Earliest records of this insect date to Mormon pioneers in the Salt Lake Valley in 1847 and to the legendary cricket plague of 1848 (Bancroft 1889, Whitney 1892).

Although most reports stress the detrimental effects of Mormon cricket outbreaks, Mormon crickets potentially provide an abundant and high-quality food source (Defoliart et al. 1982). Predation by terrestrial animals includes about 50 species of birds, mammals, and reptiles; however, references to predation by aquatic animals are few (Wakeland 1959). Mormon crickets swim readily (LaRivers 1956), as do other Orthoptera, and reference to their movements into Utah streams and lakes dates to 1848 (Bancroft 1889). Swimming crickets would be exposed to aquatic predators during migrations, but we found no reference to predation on this species by fishes.

Annual Mormon cricket outbreaks and migrations in Dinosaur National Monument (DNM), Colorado and Utah (Fig. 1), have renewed an old controversy about control of crickets by aerial spraying of pesticides (Capinera and MacVean 1987), U.S. Fish and Wildlife Service 1986, 1987). A part of this controversy concerns Park Service policy to treat crickets with natural controls, if needed (National Park Service 1986), since aerial spraying could adversely affect endangered species in DNM. The objectives of this study are to evaluate fish predation on Mormon crickets in DNM, discuss possible significance to fishes of a periodic, massive, and seasonal food supply, and comment on possible impacts of cricket controls on fishes, aquatic communities, and man.

METHODS

The availability of Mormon crickets in streams and predation on them by fishes were evaluated by visual observations, use of crickets as bait, and direct inspection of stomachs of nonnative species taken by angling, trammel nets, and electrofishing. Angling included bottom-fishing with weighted hooks and surface-fishing with floats. Mormon crickets were hooked through the thorax and abdomen. Weekly trips through the Green and Yampa rivers in 1986 and 1987 (May through July) included the season when crickets were present.

Average weights of late instar and adult Mormon crickets were obtained in 1987 by weighing 20–50 individuals from several large bands. All crickets in a 5–30-m section of road were collected and weighed on a 1,000 × 2-g platform scale. Crickets were placed in previously tared plastic bags, and subsamples were separated by sex. Cricket bands were located on Harpers Corner Road in DNM from 19 July to 14 August 1987.

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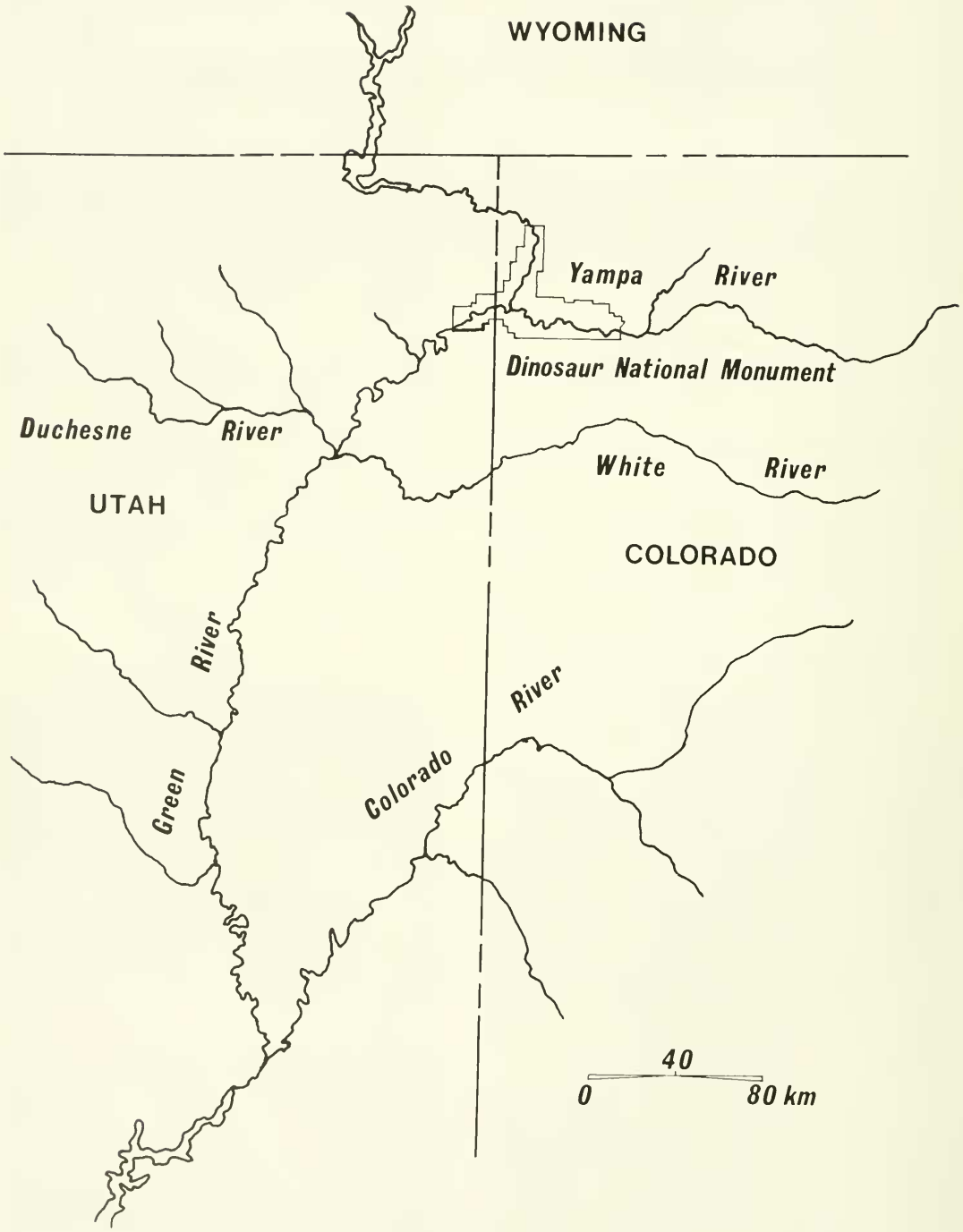

Fig. 1. Map of upper Colorado and Green river basins, Colorado and Utah.

RESULTS

Migratory Mormon crickets formed a unique and substantial organic input to the Green and Yampa rivers in DNM in 1986 and 1987. Young crickets were first observed on

TABLE 1. Numbers of fish captured using Mormon cricket, *Anabrus simplex*, as bait or fish whose stomachs contained crickets. All fish were captured in DNM 1986–1987 ([—] indicates no records kept).

Family	Species	Status	Number of individuals 1986	1987
Cyprinidae	*Cyprinus carpio*	introduced	2	12
	Gila cypha	endemic	16	29
	Gila robusta	endemic	134	185
	Ptychocheilus lucius	endemic	1	3
Catostomidae	*Catostomus latipinnis*	endemic	1	9
Ictaluridae	*Ameiurus melas*	introduced	—	8
	Ictalurus punctatus	introduced	—	161
Salmonidae	*Salmo clarki*	introduced	0	1
	Salmo gairdneri	introduced	0	4
	Salmo trutta	introduced	0	20
Cottidae	*Cottus bairdi*	native	0	1

roads in early May, and huge bands of late instars and adults migrated into river canyons in early June through July. All Mormon crickets observed encountering streams ultimately entered the water; we saw no individual turn from the water's edge for more than a few minutes. Crickets entrained in river currents varied from a few individuals per hour to concentrations of over 50 individuals/m^2 of water surface. Entrained crickets remained on the surface and continued to swim for long periods. Live, moribund, and dead individuals accumulated in eddies and remained at or near the surface for hours. Downstream from shorelines where migrating bands were entering the river, numbers averaged 10–20 individuals/m^2. Largest numbers were observed where a tributary creek intersected a migration and carried the crickets in large numbers to the mainstream. In this instance, 50 individuals/m^2 is a conservative estimate. Highest numbers were observed in eddies where crickets accumulated. In such instances, their abundance exceeded the last value, and, in minutes, hundreds of crickets climbed aboard our rafts.

A total of 430 Mormon crickets were weighed from 12 collections taken in 1987. Average weight per cricket was 3.03 g. A subsample of 112 males averaged 2.84 g (range 2.30–3.02 g), and 141 females averaged 3.12 g (range 3.07–3.27 g). Although we could not reliably estimate the biomass of crickets, we observed several bands of 1 km^2 or more entering the Green River. At 10–20 individuals/m^2, one of these bands could weigh 30–60 metric tons.

Eleven fish species, in five families (Table 1), fed on Mormon crickets from 18 May to 1 August 1987. A total of 587 fish were captured by angling in 1986 and 1987 with Mormon crickets as bait, or had crickets in their digestive systems. Included were four endemic Colorado River fishes: roundtail chub, *Gila robusta;* humpback chub, *Gila cypha;* Colorado squawfish, *Ptychocheilus lucius;* and flannelmouth sucker, *Catostomus latipinnis*. Roundtail chub and the endangered humpback chub were voracious feeders on Mormon crickets. Although bait records for 1986 were incomplete, these two species comprised 53% (N = 210) of fish captured in 1987 (N = 399) with cricket-baited hooks (Table 1). Three Colorado squawfish were captured using crickets for bait, and a fourth attempted to eat a cricket but was not landed.

When Mormon crickets were present, all fish species large enough to eat them had done so. Small individuals of aggressive, omnivorous species (channel catfish, *Ictalurus punctatus*, and black bullhead, *Ameiurus melas*) dismembered and devoured even the largest crickets. Remarkable numbers were present in some digestive tracts, distending stomachs and intestines and, in some cases, filling buccal cavities and protruding from mouths. Channel catfish and carp (*Cyprinus carpio*) were observed at the water surface feeding on crickets in eddies whenever crickets were present. The most striking example of point input and opportunistic feeding was observed 28 May 1987 at the confluence of the Green River and a small tributary in DNM. Nineteen of 21 brown trout (*Salmo trutta*), 1 of 3 rainbow trout (*Salmo gairdneri*), and 1 cutthroat trout (*Salmo clarki*) taken immediately below the inflow were gorged with crickets. However, no Mormon crickets were observed

upstream of the confluence (13-km reach), and none of 25 individuals of the same three species collected there had consumed crickets.

DISCUSSION

Mormon Crickets and Stream Ecology

The movements of large bands of Mormon crickets into the Green and Yampa rivers in DNM in 1986 and 1987 provided a substantial and high-quality organic input to this system. This must have been the case in other years of major outbreaks, such as from 1980 to 1987 in DNM (Capinera and MacVean 1987, National Park Service 1986). Mormon cricket availability may be important to the ecology of both native and nonnative fishes. This is especially true in DNM, which contains the only known spawning site for the endangered humpback chub in the Green River Basin, and one of the two confirmed spawning sites for the endangered Colorado squawfish (Tyus et al. 1987).

Various investigators have studied Green River fishes (Holden and Stalnaker 1975, Miller 1964, Miller et al. 1982, Vanicek and Kramer 1969) with emphasis on rare, native species listed or considered for listing as threatened or endangered (U.S. Department of the Interior 1985). The fauna also includes numerous nonnative fishes introduced for sport, forage, food, or by accident (Tyus et al. 1982). Food habits of native fishes are generally known (Vanicek and Kramer 1969, Jacobi and Jacobi 1982), but their seasonal use of terrestrial animals is not. Foods of nonnative species are described for other rivers (e.g., Carlander 1977), but few data exist in DNM.

Mormon cricket movements into rivers in DNM in spring provide food for stream fishes. This is a time when flooding, scouring, and annual insect emergence reduce food availability. High-water turbidity presumably reduces visual feeding efficiency of predatory fishes, yet large numbers of crickets at or near the water surface are vulnerable to aquatic predators. Cricket availability coincides with prereproductive periods for some native species, including roundtail and humpback chubs, flannelmouth sucker, and Colorado squawfish. As reported by Defoliart et al. (1982), adult Mormon crickets have a mean crude protein content of 58% and a fat content of 16.5%. Such abundant and high-quality food might enhance fish reproductive success, postreproductive recovery, or both.

We do not advocate that native fishes time reproductive behavior to cricket input. However, a demonstrable relationship between nutrition and reproductive success in these fishes would be of interest, and long-lived fishes could incorporate such unpredictable major outbreaks to advantage in life-history strategies (Smith 1981, Tyus 1986). Longevities of endemic Colorado River fishes studied to date indicate long life is an exceptional attribute of this fauna. Bonytail chub (*Gila elegans*) older than 40 years have been reported, razorback sucker (*Xyrauchen texanus*) commonly reach 30 to 40 years, and Colorado squawfish that formerly achieved 1.8 m in length must have lived even longer (McCarthy and Minckley 1987, Rinne et al. 1986). Periodic outbreaks of Mormon crickets could contribute significantly to nutrition, directly or indirectly, for a number of consecutive or disjunct years during such a long period of life.

High flows and seasonal flooding in the mainstream Green River are now reduced by dams (Joseph et al. 1977). This alters or precludes floodplain inundation and removes particulate organics through reservoir entrapment (e.g., Minckley and Rinne 1986). Flooded lowlands were formerly expansive during sustained high flows, which often exceeded mean discharge (181 m^3/second, based on an 86-year record at Jensen, Utah) by more than an order of magnitude during snowmelt (Remilliard et al. 1986). Floodplain communities were thus made available to predation by riverine fishes, as observed elsewhere (Welcomme 1979). In the Green River, Colorado squawfish and razorback sucker have been radiotracked to flooded lowlands, where they presumably feed (Tyus 1987, Tyus et al. 1987). Flood reduction and loss of allochthonous inputs may make seasonal inputs of terrestrial animals, including Mormon crickets, more important now than historically.

Mormon Cricket Control

In their natural grassland or sagebrush-dominated habitats, Mormon crickets prefer to feed on succulent, herbaceous vegetation. Damage to range grasses is considered so slight that they are not generally considered a

serious livestock competitor (Capinera and MacVean 1987, Corkins 1923, Cowen 1932). Bands of crickets migrating into croplands have resulted in economic damage that is legendary. However, reports of flying grasshoppers in early accounts (Bancroft 1889), indicate Mormon crickets did less than all the damage. Psychological effects of hordes of large, black insects invading gardens and dwellings during periodic outbreaks were nonetheless sufficient to stimulate severe countermeasures. Mechanical barriers, poisoned baits, aerial application of pesticides, and biological controls have all been used (Animal and Plant Health Inspection Service 1986, Capinera and MacVean 1987, Swain 1944, Wakeland 1959).

As mentioned, Mormon crickets provide food for many terrestrial and aquatic animals. They are also potentially valuable to man. Defoliart et al. (1982) found that dried Mormon crickets contained 2,800 Kcal/kg and valued the powder at $300/metric ton. A small (1 km^2) band of crickets (10–20 crickets/m^2) would be worth about $3,000-$7,000 based on these values. Mormon crickets are also beneficial because they feed on other insect pests, including aphids (Ueckert and Hanson 1970), and are known to scavenge on feces or carrion, converting these energy sources into food more readily usable by higher predators. Control may therefore conflict with perpetuation and management of desirable species, either through direct poisoning or indirectly through reduction in the terrestrial and aquatic food supply (Capinera and MacVean 1987, Mont and Oehme 1981).

Although government agencies currently utilize pesticides of relatively low toxicity to vertebrates (i.e., carbaryl, malathion), these chemicals can cause adverse impacts to the avifauna (Moulding 1976) and to aquatic invertebrates (Mont and Oehme 1981). Private citizens may employ even more dangerous chemicals. Direct impacts of pesticides (e.g., blow-over, accidental spraying, or washing of poisons into aquatic habitats) may be minimized by enforcement of regulations (U.S. Fish and Wildlife Service 1986, 1987). Yet pesticide contamination remains a possibility if applied near aquatic systems. If direct poisoning of nontarget animals does not occur, indirect effects, such as reduction in foods, may affect fishes.

Contamination of aquatic habitats may further occur through mass movements of pesticide-laden Mormon crickets into streams, and entrainment of other contaminated animals. If crickets consumed by fishes contain pesticides, the large number eaten by fishes suggests that substantial amounts of pesticides could likewise be consumed. This would result in death or physiologic impairment. Coincidence of cricket outbreaks, pesticide application, and fish reproduction may result in potential pesticide influence on gamete production, gametes, or young. A high incidence of vertebral anomaly (lordosis) in roundtail chub in DNM has been tentatively linked to pesticide applications (Haynes and Muth 1985).

Lastly, streams within and near DNM are renowned for sport fishing. Substantial harvests are recorded for trouts in the Green River below Flaming Gorge Dam and channel catfish throughout the upper Green River Basin. Other carnivorous fishes, including northern pike (*Esox lucius*), are also taken and eaten. If pesticides are bioaccumulated by sport fishes, an avenue exists for direct transfer of potentially damaging substances to the public.

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